Water Quality and Remote Sensing: A case study of Lake Naivasha, Kenya

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our future through science

Outline

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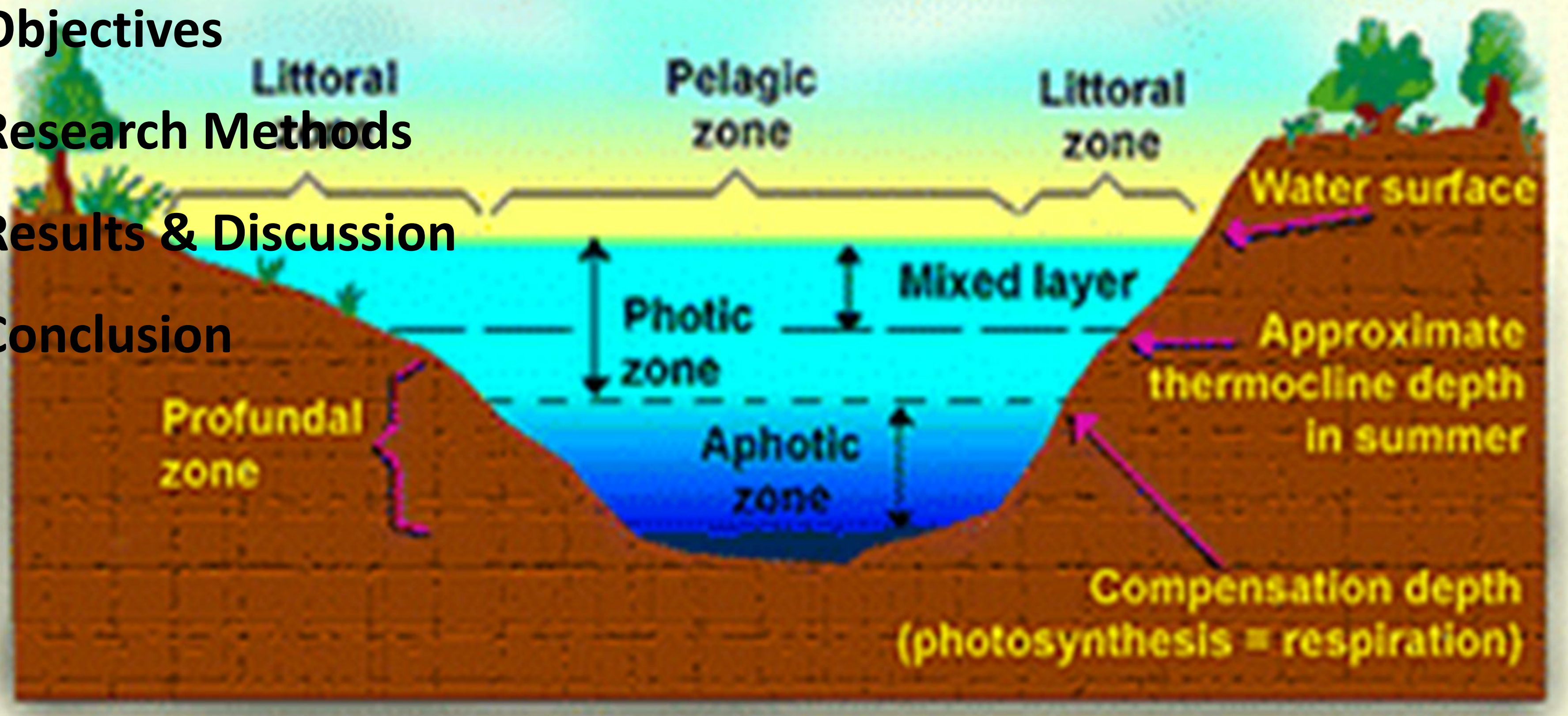

Background

- Freshwater ecosystems are limited renewable resources essential for socio-economic development and environmental sustainability
- Need for constant monitoring of this resource to ensure sustainable planning and management
- Satellite remote sensing, hence, potentially provides a tool for monitoring water quality & other environmental phenomena because it offers opportunity for data collection on systematic synoptic and temporal scales, esp. in inaccessible areas
- Study focused on estimating euphotic zone depth (Zeu) from MERIS-derived diffuse attenuation coefficient Kd(490)
- Zeu (euphotic- ‘well lit’ in Greek) is the depth at which light intensity/ solar radiation falls to 1% of the value at the surface in a water column. It is a quantitative measurement of water clarity/ turbidity
- Dependent on water constituents: phytoplankton pigments, Coloured Dissolved Organic Matter, Non-Algal Particles, water molecules


Ocean Light Zones
Euphotic Zone
Disphotic Zone
Aphotic Zone
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Why Euphotic depth?

- Primary production occurs within this depth because there's sufficient light for photosynthesis
- Approximately 90% of all aquatic life lives within this depth
- Transfer of heat and greenhouse gases (CO_2 and O_2)
- aesthetic quality of the water

Research Objectives

To quantify and map euphotic zone depth (Zeu) using Medium Resolution Imaging Spectrometer (MERIS)

- To develop a Kd(λ) model using insitu remote sensing reflectance (Rrs(λ)) data
- To assess the empirical relationship between Kd(PAR), Kd(490) and Zeu
- To assess the accuracy of atmospheric correction processors, i.e. Case 2 Regional and Eutrophic Lakes, and Bright Pixel atmospheric correction (BPAC)
- Validate the above-mentioned models using MERIS imagery
- Map Zeu using MERIS

Research Methods

Study Area

- shallow freshwater lake (avg depth 5m), Lat 0°45' S, Lon 36°20’ E, altitude 1890m msl
- Located 80km NW of Nairobi, in the water-scarce zone of the Kenyan Rift Valley
- 2nd largest freshwater lake in Kenya after Lake Victoria, in a region dominated by soda lakes
- Plays a key role in local and national socioeconomic development (supports fishing, intensive horticulture and floriculture industries, & a geothermal power generation station)
- Declared a wetland of international importance in 1995 under the Ramsar Convention

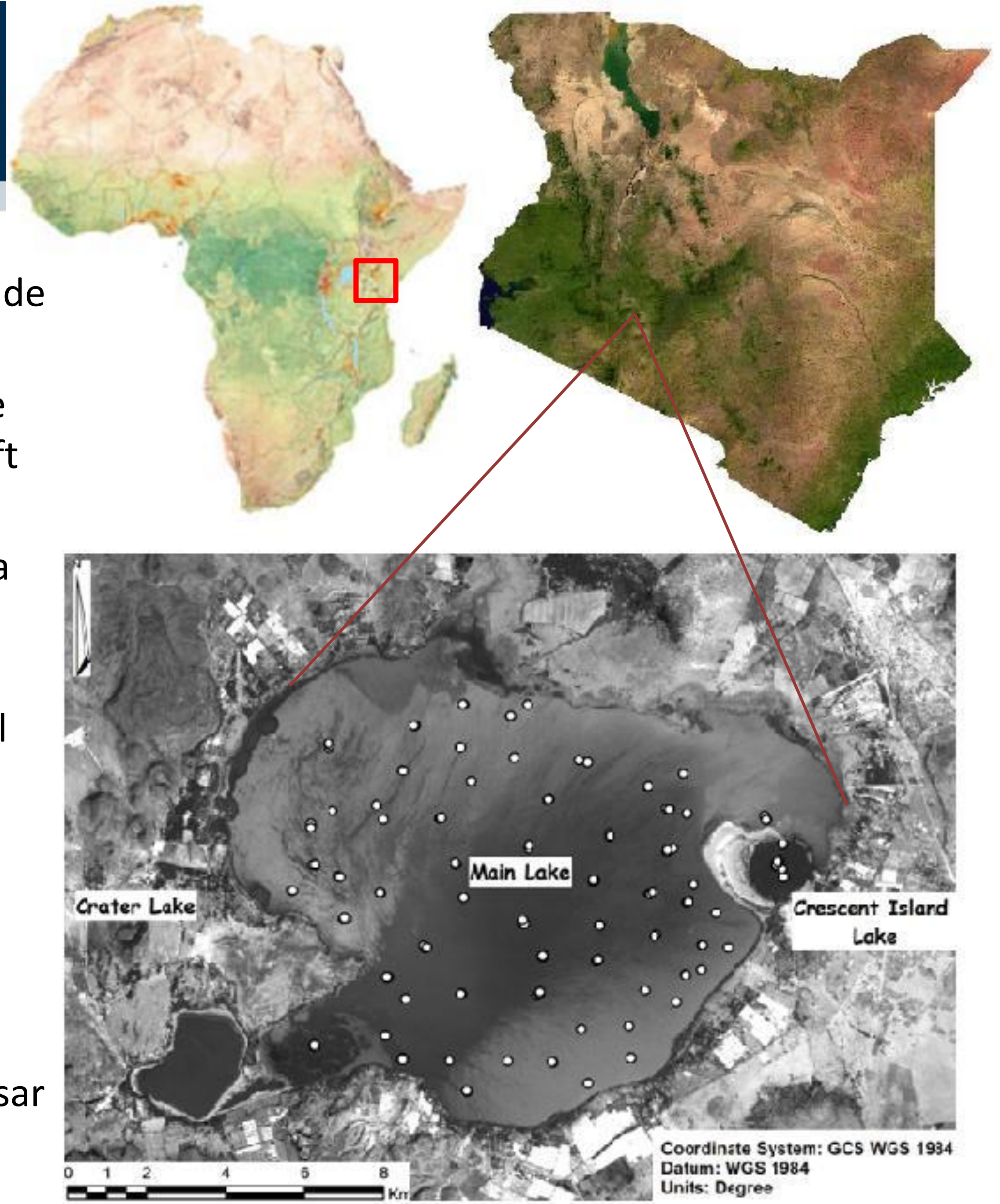

Fig 1: Location of Lake Naivasha and the sampling stations

Data Acquisition
In situ data

Measurement	Variable	Instrument
Radiometric	**Above-water**	TriOs RAMSES Radiance and Irradiance Sensors
	Upwelling radiance (Lu(λ))	
	Above-water downwelling irradiance ($E_d(\lambda)$)	
	Under-water	
	Under-water downwelling irradiance ($E_d(z;\lambda)$)	
Ancillary data	Lake state and sky conditions	Photograph camera
	Transparency	Secchi Disk
	Geographic locations of sample points	Garmin 6S GPS
	Date, location description	Physical observations
Water Samples	Chlorophyll concentration	Spectrophotometer
	Coloured Dissolved Organic Material	Spectrophotometer
	Suspended Particulate Matter	Gravimetric method

Table 1: *In situ* measurements taken in Lake Naivasha from 17 Sept to 03 Oct 2010

MERIS overpass times were acquired from the European Space Agency (ESA) & during these days, i.e. 17, 20, 23, 26, 29 September 2010, intensive radiometric measurements were collected within 1 hour of the scheduled overpass time for calibration and validation of the Kd and Zeu models

Potential RS datasets

Sensor	Spatial Resolution (m)	Frequency	Spectral Coverage	Available water quality products	Lifespan
MERIS	300/ 1 200	1 – 3 days	412-1050	TSM, Chl a, Kd(490), Z_{90}, Turbidity index, $a_{t/CDOM/SPM}(443)$	2002-2012
SeaWIFS	1100	Daily	402-885	CDOM index, PAR, Chl a, Kd(490)	1997-2010
MODIS Terra/ Aqua	250/ 500/ 1 000	1 – 2 days	405-14,385	CDOM index, PAR, Chl a, Kd(490), FLH	1999–date/ 2002 -date

Table 2: Summary of potential RS datasets for inland water quality monitoring

- Landsat, AVHHR, MSG
- Sentinel 2 & 3 (to be launched in 2013 after the death of MERIS)
- ❖ Level 1B Full Resolution was acquired (17, 20, 23, 26, 29 Sept 2010) from ESA

Atmospheric correction

Processors used:

- MERIS Neural Network processors, Case 2 Regional and Eutrophic Lakes (BEAM)
- Optical Data Processor of the European Space Agency (ODESA) Bright Pixel atmospheric correction (BPAC)

Algorithm Development

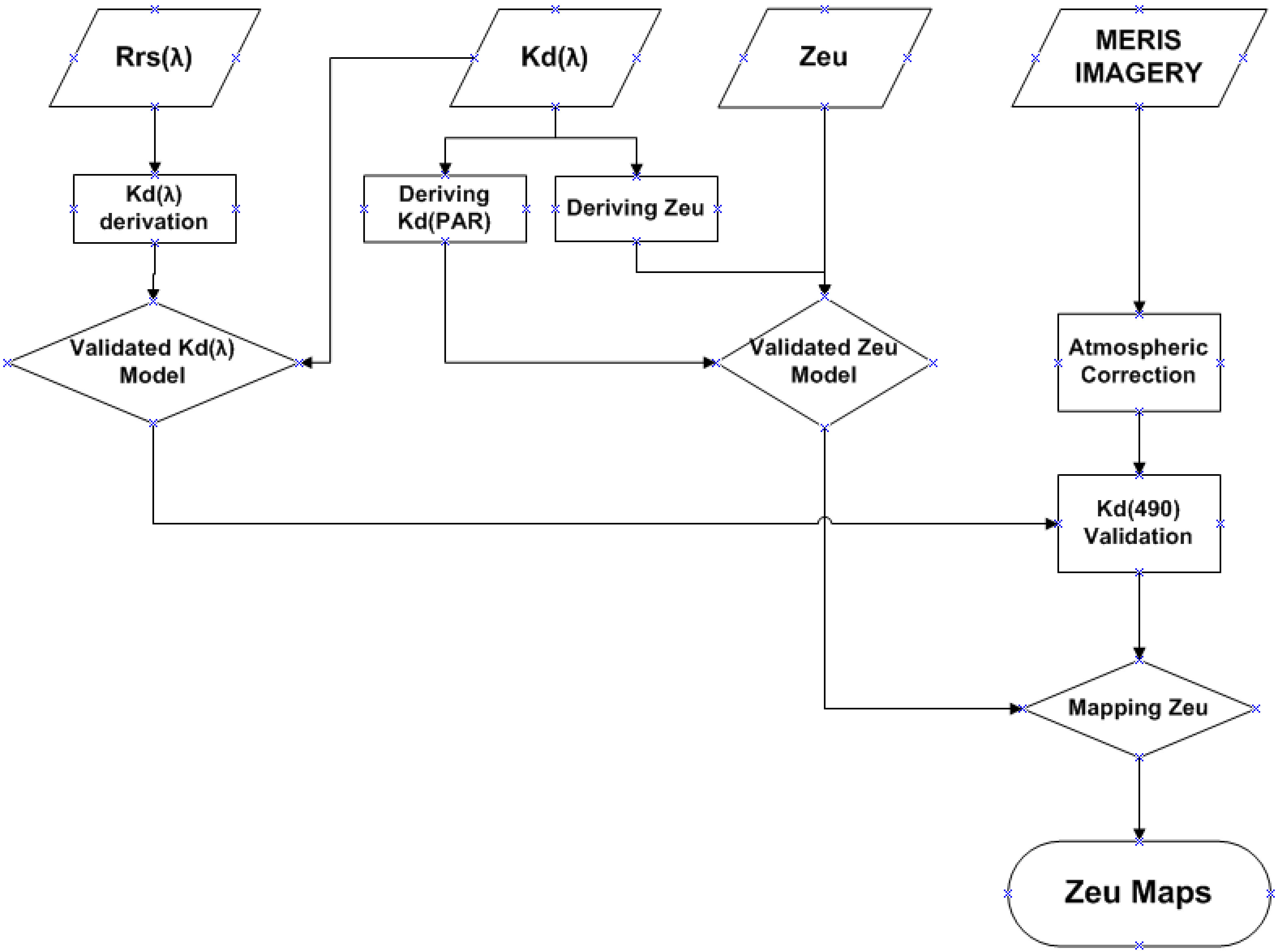

Fig 2: Algorithm development and data processing chain

Results

In situ measurements

Optically active component	N	Min	Max	Range	Mean	Std
$a_t(490)$ (m^{-1})	85	2	11.1	9.1	6.37	1.474
C_{spm} (mgl^{-1})	85	6.8	101	94.2	37.8	18.6
$C_{chl\ a}$ (mgm^{-3})	95	12.95	71.25	57.3	30.41	9.07
$K_d(490)$ (m^{-1})	85	2.466	11.93	9.464	6.59	2.748
$K_d(PAR)$ (m^{-1})	73	1.729	6.721	4.992	4.31	1.71
Secchi disk depth (m)	85	0.21	0.77	0.56	0.38	0.11
Z_{eu} (m)	73	0.685	2.663	1.978	1.15	0.4095
$a_{ph}(440)$	136	0.034	0.15	0.116	0.105	0.0224
$a_{CDOM}(440)$	136	0.5	1.8	1.3	1.252	0.3065

Table 3: Summary of optical components derived from *in situ* measurements

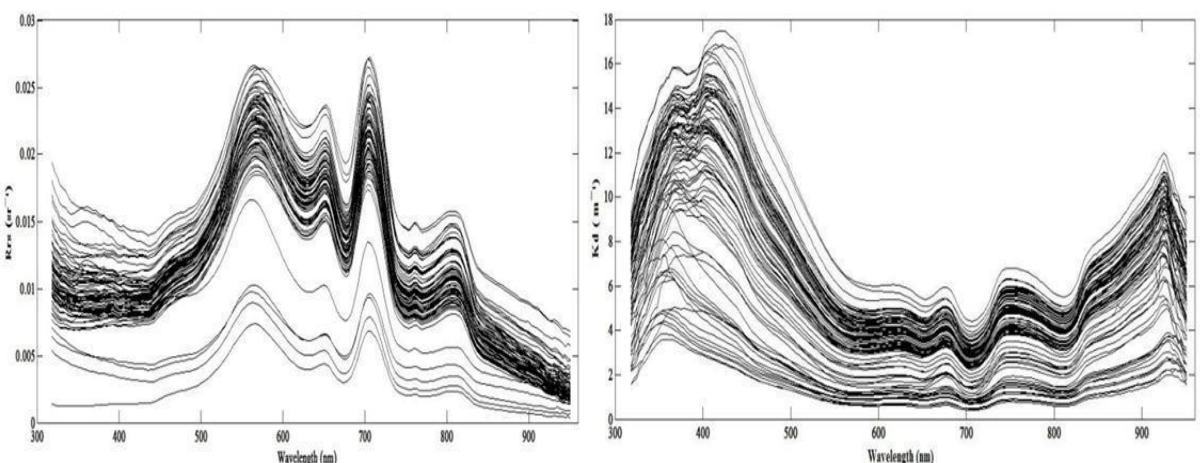

Fig 3: Spectral Remote sensing reflectance (left), Diffuse attenuation coefficient (right)

- high Chl *a* concentration citing high phytoplankton biomass in the lake
- evidenced also by the high 709 nm reflectance peak

MERIS processing

Atmospheric correction

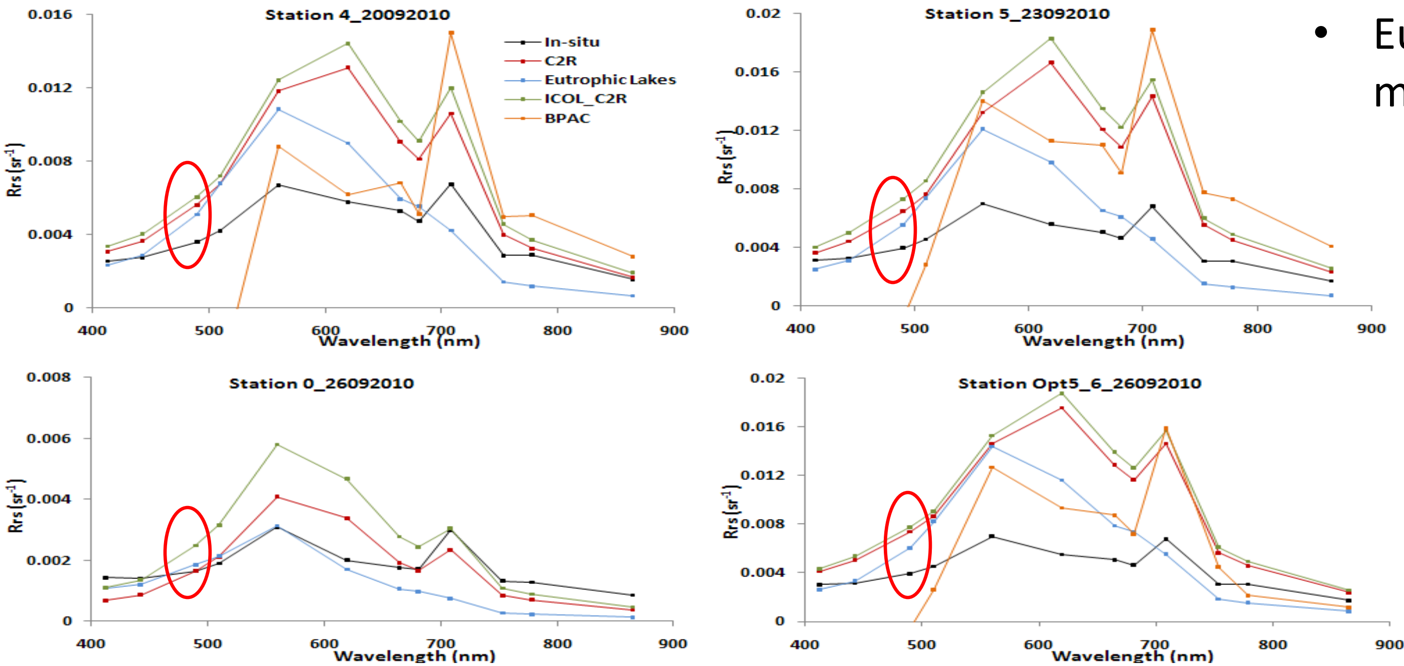

Fig 4: Comparison of atmospheric correction processors to in situ measurements

- Eutrophic Lakes was most accurate at 490nm

Model validation using MERIS

	RSME	MAE (%)
K_d(490)	0.426	31.336
Z_{eu}	0.236143	20.31099

Table 4: Validation statistics of Kd(490) and Zeu models on MERIS

Zeu Mapping

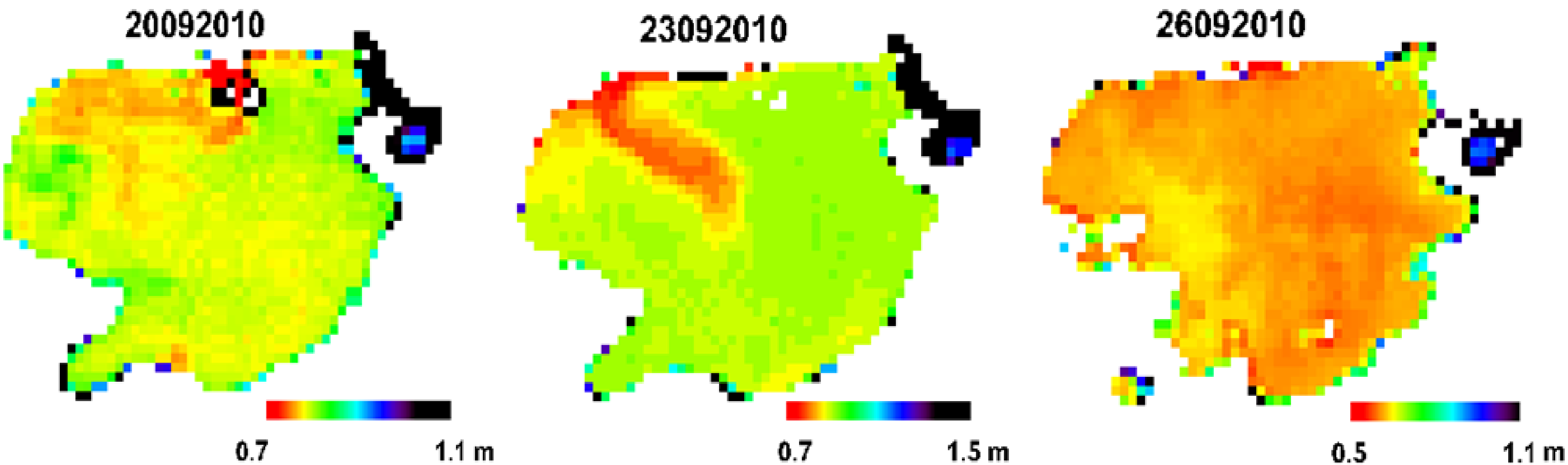

Fig 5: Maps showing distribution of Zeu in the lake on three days, 20, 23 and 26 September 2010

- A spatiotemporal variation of Z_{eu} captured across the 3 days

In conclusion

- Results illustrate that MERIS FR can effectively map the optical water parameters in shallow eutrophic inland waters like Lake Naivasha
- Further show the opportunity of using satellite remote sensing data like MERIS to continually monitor water quality of highly variable inland waters.
- Atmospheric correction results indicate the challenges that are faced when it comes to accurately perform atmospheric correction in optically complex inland waters.
- There is still a gap in African continent when it comes to using remote sensing to monitor water quality.
- Strong in situ networks need to be established to develop and/ or calibrate more robust algorithms suitable for African waters.

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THANK YOU